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ABSTRACT

A study focused on answering questions about fidelity levels of maintenance training simulators in a relatively simple electromechanical troubleshooting task. Two aspects of simulator fidelity were manipulated: physical fidelity and functional fidelity. The paid participants in the study were 100 male and female college undergraduates at George Mason University. In the training phase, subjects were trained in 1 of 10 training conditions and asked to troubleshoot and solve problems on a simulator. The training conditions consisted of all combinations of three levels--high, medium, and low--of physical and functional fidelity and a no-training condition for a control group. Subjects were then asked to solve problems on the actual equipment to assess learning transfer. Time-to-solution, number of tests to solution, and number of solution attempts were used to assess transfer. Results indicated increased feedback during training was generally associated with higher levels of performance during transfer. Time-to-solution was found to be most sensitive to fidelity manipulations. Trainees appeared to adopt one of three strategies during transfer: logical, sequential, or haphazard. Persons high in general analytic ability took longer to reach a correct solution but made fewer tests and solution attempts. (Thirteen tables are appended.) (YLB)

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Maintenance Simulator Fidelity in Electromechanical Troubleshooting Training

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Abstract

A key issue in the area of simulator-based training concerns the degree to which a simulation may depart from reality before its training effectiveness is impaired. Unfortunately, at present there is a conspicuous lack of empirical data that one might use to specify minimal fidelity values for training simulators. The present study was undertaken as part of a larger program of research aimed at identifying such values in the area of maintenance training simulation. A major objective of this on-going work is to provide the U.S. Army with empirical data upon which engineering guidelines for maintenance training simulators might be based.

Two aspects of simulator fidelity were manipulated, viz., the degree to which a training simulator "looked like" the actual equipment it was simulating (physical fidelity), and the degree to which it "acted like" real equipment (functional fidelity). Three levels of physical fidelity (high, medium and low) and three levels of functional fidelity (high, medium and low) were investigated in an electromechanical troubleshooting task. A

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simple transfer of training design in which subjects were first trained on a simulator and then tested on actual equipment was used to assess learning transfer.

One hundred subjects were tested on several individual difference measures and then randomly assigned to one of nine simulator-training conditions or a control group receiving no training. During training, subjects were asked to troubleshoot and solve six problems on a particular simulator. Immediately following training, subjects were required to solve eight problems on the actual equipment trainer. Time-to-solution, number of tests to solution and number of solution attempts were used to assess transfer.

Results indicated that increasing feedback during training was generally associated with higher levels of performance during transfer. However, this pattern was not uniform across all training conditions. Time-to-solution was found to be most sensitive to fidelity manipulations. Among the interesting individual difference patterns to emerge was the finding that persons high in general analytic ability took longer to reach a correct solution, but made fewer tests and solution attempts.

Maintenance Simulator Fidelity in Electromechanical Troubleshooting Training

A key issue in the design of training devices and training programs which are based around training devices is the degree to which the training device must duplicate the actual equipment for which training is required. This degree of similarity to the actual equipment is called simulator fidelity (Hays, 1980). Despite their proven effectiveness, designing simulators and training devices with too high a level of fidelity may not be cost effective. Unfortunately, at present there is a conspicuous lack of empirical data that training developers may use to specify minimal fidelity values for training simulators. The present study was undertaken as part of a larger program of research aimed at identifying such values in the area of maintenance training simulation. A major objective of this on-going work is to provde the U.S. Army with the empirical data upon which engineering guideines for maintenance training simulators might be based.

Previous research has, for the most part, been concerned with evaluating the training effectiveness of whole devices rather than systematically investigating the effect of various degrees of fidelity (Ayers, Hays, Singer & Heinicke, in press). Several notable exceptions to this generalization are the research efforts of Wheaton and Mirabella (1972), Mirabella and Wheaton (1974), Johnson and Rouse (1982), Baum, Reidel, Hays and

Mirabella (1982) and Johnson and Fath (1983). Each of these efforts systematically manipulated the characteristics of the devices used to train the criterion tasks. However, only Baum, et al. (1982) manipulated the physical and functional characteristics of the training simulators. In this study, training simulators of various degrees of physical and functional fidelity were used to train a mechanical adjustment task. A significant effect of physical fidelity was found, however, no main effect for functional fidelity or interaction effects for the two fidelity dimensions was found. Baum, et al. (1982) propose additional research using different tasks to further specify the effects of physical and functional fidelity. The present study is part of the ongoing effort to accumulate empirical data on fidelity effects as well as the effects of other training system variables. Many of these variables are cataloged and briefly discussed in Hays and Singer (1983).

The current work is part of this basic research aimed at investigating the degree of functional and physical fidelity needed in maintenance simulators to ensure maximum transfer of training. A unique feature of this research is the construction and use of a generic reference system for simulation and actual equipment training (AET). Degraded simulations of this reference system afford the opportunity to generate systematic data on the effects of both physical and functional fidelity on transfer of training. The present study focuses on answering questions about fidelity levels in a relatively simple electromechanical troubleshooting task. Later studies, however, will be more

parametric in nature, and will involve fidelity-interactive variables such as task difficulty, trainee experience and aptitude, stage of training, transfer variables, etc.

Additional goals of the present research are to: develop operational definitions of physical and functional fidelity, collect individual differences data in order to determine how fidelity interacts with these differences and develop scales on the dimensions of physical and functional fidelity.

Two aspects of simulator fidelity were manipulated, viz., the degree to which a training simulator "looked like" the actual equipment it was simulating (physical fidelity), and the degree to which it "acted like" real equipment (functional fidelity). The functional aspect of fidelity was the most difficult to operationalize. There are many ways in which any equipment can function. Functionality can describe the way controls or displays operate and the results of those operations, the way the operator functions in conjunction with the equipment, the amount of feedback the operator receives from the equipment, etc. In this research, we have chosen to manipulate the feedback aspect of functionality. We realize that this is not the only aspect of functionality, but it is a potent aspect and is one that is amenable to manipulation in this context.

Method

Subjects

One hundred male and female college undergraduates drawn primarily from introductory psychology courses at George Mason

University served as paid participants ($5.00/hour). Subjects also received course credit for participation. All participants were treated in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

Materials

Individual differences measures. Prior to serving in subsequent phases of the experiment, all subjects completed a two-hour test battery which included the following measures: (1) Group Embedded Figures Test (GEFT), (2) Bennett Mechanical Comprehension Test (BMC), (3) Graduate Record Examination - Analytic (GRE-A), (4) Rotters Locus of Control Scale (LOC) and (5) Holland's Vocational Preference Inventory (VPI).

MINC-11 Computer. All experimental activities are controlled and monitored by means of MINC-11 computer. The computer controls the reference system and associated simulators and also records and stores all subject actions during the training and testing phases of the experiment.

Reference System. The reference system and its associated equipment may be described as follows. Twenty-eight electromechanical relays and five-solid state pullup panels are interconnected to eight output devices (viz., fan, water pump, solenoid valve assembly, three lights, TV monitor and sound generator and speaker). When operating properly (i.e., when no faults have been introduced into the system) all of the output devices work. However, when a relay or pullup panel is faulted by the experimenter, associated electromechanical relay/pullup

panels and one or more of the output devices do not work. The subject's job is to discover which relay or pullup panel assembly is at fault. To do this he or she must first detect which output device(s) is not working. Once this is done, his or her job is to discover which associated relay or pullup panel assembly is at fault.

Hand-held Tester. Relays are tested by means of a specially designed hand-held tester. To test a relay with this device the trainee dials in the number of the relay he or she wishes to test, places the probe on the relay checkpoint, and then presses the test button located on top of the unit. If the relay is "good" (i.e., it is operating properly), a green light will illuminate on the face of the tester. If the relay is not working, the green light will not illuminate. A cable connecting the hand-held tester to the MINC-11 computer is used to signal when a test has been reqested. Recording of tests and times is done automatically.

Reference System Faulter Panel. Individual relays and pullup panels are faulted by means of a faulter panel located in the experimenter's room adjoining the reference system testing room. This device consists of a number of lights and switches. Each switch corresponds to a particular relay or pullup panel assembly. To fault a component, the experimenter merely throws the switch appropriate to the component he wishes to fault. Such action causes the component to stop working. All interconnected relays, pullup panels and output devices then cease to function. Lamps on the face of the panel give the experimenter

instant information as to which component has been faulted.

Simulators. Three major training simulators, each differing along the physical fidelity dimension, are used in the project (i.e., a high physical fidelity simulator, a medium physical fidelity simulator and a low physical fidelity simulator). These simulators, when coupled with one of three levels of feedback (i.e., full, partial or no feedback), provide nine possible training simulators.

High Physical Fidelity Simulator. This simulator is the reference simulator. Subjects who train on this device experience the same physical characteristics as those trained on the a "actual equipment" itself.

Medium Physical Fidelity Simulator. This device is quite similar to the reference system in terms of its size and appearance, however, there are a number of notable differences. For one thing, half of its components (relays, output devices, etc.) are "real" (actually duplicate those on the reference system), whereas half are "unreal" (mockups). Thus, trainees using this system are able to test and/or observe the responses of some components and devices, but not others.

Low Physical Fidelity Simulator. Visually, the low physical fidelity simulator is quite different from either the medium or high physical fidelity simulators. Essentially, it is a symbolic representation of the reference system. Relays, pullup panels and output devices are represented by rectangles, and lines between rectangles are used to

indicate wiring connections. Testing and checking of relays and output devices (if required in a particular training condition) can be done in two ways, viz., either by pressing the particular pushbutton associated with the device under consideration and observing the appropriate response light, or by using the hand-held tester. It should be noted that only the latter method is used in the present research.

Simulator Faulter Panel. A specially constructed faulter panel is used to fault relays and output devices on the medium and low fidelity simulators described above. It is quite similar to the faulter panel used with the reference system. That is, faults are introduced by simply throwing a switch associated with a particular component. A universal coupler permits the faulter to serve as a control box for both the medium and low physical fidelity simulators.

Design and Procedure Subjects were first tested on the battery of individual difference measures described above. Subjects were tested in groups of five to ten and testing lasted approximately two hours. At the end of the testing session, each subject was scheduled to return the following week for the training and transfer phase of the experiment.

In the training phase, subjects were trained in one of ten training conditions described in Figure 1. These training

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Insert Figure 1 about here

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conditions consisted of all combinations of three levels of physical and functional fidelity and a no training control group. After a five minute break, all subjects were tested on the actual equipment (reference system).

The simulator condition in which a particular subject was trained was determined quasi-randomly, i.e., subjects were scheduled for a session on a completely random basis, while the training condition for any given session was systematically determined to ensure that an equal number of subjects were trained in each of the training simulator conditions.

Upon arrival for the training and transfer phase, subjects were ushered into the experimental room housing the appropriate training simulator for their group. They then listened to one of nine versions of taped instructions explaining the use of the apparatus and the general intent of the training. The no training control group received one of the nine instruction sets, assigned randomly and then read a set of non-related psychology readings for a period of time equivalent to the time taken in the training conditions. During the instructions the experimenter remained in the room with the subject in order to demonstrate various equipment operations. Immediately after the instructions were completed, the experimenter left the room and the training session was begun.

During training, all subjects received eight training problems (or "faults"). Three sets of eight problems were used. Each subject was trained on one of the three sets, and this was randomly determined. All three problem sets were matched in

terms of problem difficulty based on baseline troubleshooting data previously gathered on the reference system.

All faults during training were initiated by the experimenter. When a problem was begun (through the initiation of a fault), the subject was signalled by a start tone. The subject's task was then to determine which of the possible 28 components was at fault. Depending on the simulator in use, this either involved testing relays and output devices, testing relays only, or, as was the case in the no feedback conditions, merely examining and studying the components and relatioships between them. Once a problem was solved, an intertrial interval of approximately 30 seconds was begun. At the end of this interval, the process was repeated for each of the remaining seven problems.

Upon completion of the training phase, each subject received a five-minute break. The transfer portion of the session was then begun. First, however, subjects were introduced to the reference system via a second set of recorded instructions which were identical to those heard by subjects in the high physical/ high feedback training condition.

During the transfer test, each subject received six problems. The test set was composed of the following faults: 9, 15, 11, 10, 19, 1. The order of faults was randomized for each subject. Experimental sessions lasted between one and two hours depending on the subject's performance. Degree of transfer was assessed with the following dependent variables: time to first solution (TFS), inter-response time (IRT), inter-test time (ITT), total time (TTIME), number of tests

repeated (TREP), number of solutions (NSOL) and number of solutions repealed (SOLREP).

The subjects were then thanked, asked if they had any questions, and then paid for their services.

Results and Discussion

ANOVA on Tests, Solutions Attempts, and Time-to-Solution

A 3 x 3 factorial analysis of variance comparing the transfer performances of the various training groups was run on each of the three of the dependent variables, viz., number of tests, attempts-at-solution and times-to-solution. Summaries of these analyses are given in Tables 1, 2 and 3. Means and standard deviations are shown in Tables 4, 5 and 6.

Insert Tables 1 thru 6 about here

The results of these analyses can be summarized rather easily. As can be seen in Tables 1 and 2, there were no significant main effects or interactions for physical fidelity and feedback for number of tests and attempts-at-solution. As can be seen in Table 3 however, there was a significant main effect for both physical fidelity and feedback for time-to-solution, $p<.04$ and $p<.001$ respectively. The interaction of physical fidelity and feedback for time-to-solution was not significant.

With respect to the time-to-solution variable, an examination of Table 6 indicates the nature of the two significant main effects quite clearly. First, decreasing levels of feedback are

generally associated with longer solution times. This makes good intuitive sense in view of the fact that one might expect that with more information (feedback) problem solving is easier and therefore quicker. Secondly, decreasing levels of physical fidelity were generally associated with longer solution times.

One might also note that the lowest physical fidelity and feedback condition displays the largest standard deviation. This may reflect a differential effect of individual differences in troubleshooting ability.

In summary, it appears that time-to-solution is the most sensitive dependent variable (of the three examined) in the present task. This fact may be very important for training time critical tasks.

Post Hoc Comparisons of Control and Training Group Data

To determine whether, in fact, the criterion task (troubleshooting on the reference system) required sophistocated training procedures, the data from each of the nine simulator conditions was compared with that of the no-training control group. Dunnet's (1955) multiple comparison procedure for comparing several treatments with a control was used. The results of these comparisons are shown in Figure 2 below.

Insert Figure 2 about here

It is interesting to note that although all training groups performed better than subjects in the no-training control group

(fewer tests, fewer solution attempts, shorter times-to-solution), many performance differences were not statistically significant. These data strongly suggest, therefore, that in future studies a more difficult criterion task should be chosen.

Subject Strategies During the Transfer Phase. Since trainees were free to solve troubleshooting problems any way they wished, it was felt that a number of different strategies would be used by the subjects during the transfer phase. This was supported by observations of experimenters who noted that while "some subjects appeared to simply test every component, regardless of the problem at hand", others "seemed to attack each problem logically and carefully using a minimum of tests and solution attempts."

To help pinpoint what specific strategies were in fact being used by subjects during the transfer phase, an analysis of the numbers and sequences of tests, solution attempts and checks of output devices was undertaken in the following manner. First, an overall examination of the data was done which revealed that problems tended to be solved in one of three ways, viz., either logically, using a sequential testing strategy, or randomly, with no apparent strategy at all.

When troubleshooting "logically", a subject appeared to trace relays, pullup panel and output device interconnections in a way congruent with the way the components were actually connected. The order of tests, output device checks and solutions seemed to reflect an overall comprehension of the "logic" of the system.

Subjects using the "sequential" troubleshooting strategy typically began with a particular relay, and then tested all subsequent ones in a fixed and predictable numerical order. Usually, the subject began with either relay 1 or 28, and then worked forward or backward, respectively. It appeared that the subjects believed the components were connected in a strictly numerical order even though this was not the case.

When a "random" strategy was used, no discernable pattern or logic was apparent in the tests, checks and solutions that the trainee offered. Subjects seemed to test the components and offer solutions haphazardly.

To determine if some subjects tended to rely on one of these strategies to the exclusion of the others, the data from each subject was examined in more detail. For each subject, the number of transfer problems that appeared to be solved using each type of strategy was determined. If a subject solved four or more of the six criterion problems using a particular strategy, he or she was classified as either a "logical", "sequential", or "random problem solver." The results of this analysis are shown in Tables 7 and 8.

Insert Tables 7 and 8 about here

First, it should be noted that 90% of the subjects were found to use a consistent strategy during transfer. Of these, 84% used a logical approach, 12% a sequential approach, and 4% a random or haphazard strategy. These percentages are particularly striking in view of the common feeling of experiments that many

of the subjects did not appear to solve the problems "logically". The data seem to indicate otherwise!

In view of the large number of subjects who used a logical strategy to solve the transfer problems, questions regarding the distribution of strategies across groups are a moot point. It is interesting to note, though, that subjects trained in the high and medium physical fidelity training conditions were somewhat more likely to choose and use a single problem solving strategy during transfer than their low physical fidelity counterparts.

Relations between Individual Difference Measures and Dependent Variables. The eight dependent variables were factor analyzed (principal factoring with interaction, Varimax rotation) with three factors emerging:

1. Time:
   - time to first solution (TFS)
   - inter-response time (IRT)
   - inter-test time (ITT)
   - total time (TTIME)
2. Tests:
   - number of tests (NTEST)
   - number of tests repeated (TREP)
3. Solutions:
   - number of solutions (NSOL)
   - number of solutions repeated (SOLREP)

The rotated factor matrix appears in Table 9.

Insert Table 9 about here

Pearson correlations between each individual difference measure and each dependent variable across all conditions appear in Table 10.

Insert Table 10 about here

Clearly of all the individual difference measures, GRE-A was found to be the most consistently related to the task, demonstrating a significant correlation with five of the eight dependent measures. Persons with strong analytical ability attempt fewer solutions, attempt fewer tests and take longer time on the task. Similarly, individuals with high masculinity interest (VPI-M) spend more time on the task. However, the longer time spent on the task by those individuals need not imply poorer performance. It may well be that these individuals are pursuing a more thoughtful, logical strategy which is initially more time consuming. People lacking these abilities and interests may have less tolerance for the task, therefore adopting a sequential strategy which will arrive at the correct solution more quickly, although at the expense of attempting more tests and incorrect solutions. Future work investigating the individual differences associated with various strategies will clarify this matter.

The remainder of the correlations are somewhat more scattered but most are consistent with expectations. For example:

- field independent people (GEFT) attempt fewer incorrect solutions;
- individuals with realistic interests (VPI-R) attempt

fewer tests;

- people with strong mechanical comprehension (BMC) make fewer tests and also repeat fewer tests.

Interaction Between Training Conditions and Individual Difference Variables. In order to investigate the possibility that different individual difference patterns might emerge in different training conditions, correlations between individual differences and each of the dependent variables were computed separately for each level of physical and functional fidelity used in training. The correlations for the "time" measures appear in Table 11, the "test" measures in Table 12 and the "solution" measures in Table 13.

Insert Tables 11, 12 and 13 about here

Most of the correlations in Table 11 are consistent with the general trend of results discussed in the previous section (i.e., people with strong mechanical and analytic abilities/interests spend more time on the task). This is particularly true for the medium physical fidelity condition. Perhaps there is something about this training condition that encourages the adoption of different strategies and those people who have interest and ability related to the task use an initially more demanding logical approach, whereas those lacking these interests select a sequential strategy. Conceivably the other levels of physical fidelity may force a more uniform strategy.

The largest number of correlations across training conditions occurs with the VPI-I scale, which measures the subject's intellectual interests. Persons high on this scale tend to "think through" problems and their longer times support this trend.

Tables 12 and 13 are also consistent with the results discussed previously. Persons with high analytic abilities make fewer tests and attempt fewer solutions.

An interesting pattern can be noted on the Locus of Control scale in Tables 12 and 13. Field independent people made more tests in the high physical fidelity condition and attempted more solutions in both the high physical fidelity and low feedback conditions. However, they made fewer tests and fewer soltuions in the low physical fidelity condition. A ready explanation for these results is not available at this time.

In summary, clearly the relationship among strategies employed, individual differences and the dependent variables needs further exploration. In addition, the factor analysis leads logically to the production of the three factor scores of time, tests and solutions. It is recommended that in future analyses, these factor scores replace the eight dependent variables used currently. This will greatly reduce the analyses needs and substantially clarify the general trends in the data. Furthermore, a multiple regression strategy will be pursued wherever possible, using individual differences, scaling of the training conditions, and their interactions to predict these factor scores. This approach will eliminate the covariance problems of the predictors and is well-suited for discovering

adaptive training effects.

Summary and Conclusion.

Although it would be premature, if not foolish, to draw firm conclusions based on a single study, a few trends are noteworthy. Some of the major ones are:

--Time-to-solution would seem to be especially sensitive to physical and functional (feedback) manipulations.

--Increased feedback appears to make troubleshooting easier, and therefore quicker, regardless of physical fidelity level.

--Trainees appear to adopt one of the three strategies during transfer, i.e., either a logical strategy, a sequential strategy, or a haphazard strategy.

--Subjects trained on the high and medium physical fidelity simulators seem to be more likely to adopt a single trouble-shooting strategy than their low fidelity counterparts.

--GRE-Analytic test scores appear to relate most signifi-cantly and consistently to transfer test performance.

Future Plans

A number of studies are scheduled and/or under consideration for Year 3 of the project. Some of them include:

--Cost Study - This research will focus on the effects of both "imagined" and "actual" (i.e., out-of-pocket) costing of tests and solutions on troubleshooting strategy and other dependent variables of interest (total-time-to-solution, number of tests, etc.).

--Problem Difficulty Study - In this study, the effects of problem difficulty during training and/or transfer on transfer performance will be examined.

--Instructional Set Study - Effects of various instructional sets on transfer and strategy selection will be examined.

--Generic Training Gereralization Study - The possible transfer effects between generic training done on the reference system trainer (and/or simulators) and subsequent testing on a "real world" task on an actual training device.

--Fidelity Scaling Study - Several small studies focusing on issues surrounding the scaling of fidelity and subjects' attitudes toward simulation are anticipated.

--Amount of Training Study - This study would focus on the degree to which amount of training on the simulator influences subsequent transfer performance on the reference system.

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		Physical Fidelity		
		High	Medium	Low
Feedback Level	Full	All relays output devices present Hand-held unit provides feedback; output devices function	Some relays and outputs real; some mockups Hand-held unit provides feedback; output devices or symbols function	Pen and Ink drawing Hand-held provides feedback; symbols function
	Partial	All relays output devices present Hand-held unit provides feedback; output devices do not function	Some relays outputs real; some mockups Hand-held unit provides feedback; output devices do not function	Pen and Ink drawing Handheld unit provides feedback; outputs do not work
	No	All relays and output devices present Hand-held unit does not provide feedback; output devices do not function	Some relays and outputs real; some mockups Hand-held unit does not provide feedback; output devices do not function	Pen and ink drawing Hand-held unit does not provide feed back; output devices do not work

No Training Control Group

Figure 1. Study Experimental Design

		Physical Fidelity		
		High	Medium	Low
Feedback Level	Full	Time p<.05 Solutions n.s. Tests n.s.	Time n.s. Solutions n.s. Tests n.s.	Time n.s. Solutions n.s. Tests p<.05
	Partial	Time p<.05 Solutions n.s. Tests p<.05	Time n.s. Solutions n.s. Tests n.s.	Time n.s. Solutions n.s. Tests n.s.
	No	Time n.s. Solutions n.s. Tests n.s.	Time n.s. Solutions n.s. Tests n.s.	Time n.s. Solutions n.s. Tests p<.05

Figure 2. Results of Dunnet's Test Comparing Training-Group Times, Solutions and Tests with Those of No-Training Control Group

TABLE 1

Summary ANOVA of Mean Number of Tests During the Transfer Test for the Various Simulator Training Groups

Source	SS	df	MS	F	Tail Prob.
Between Subjects	6252.17	1	6252.17		
Physical Fidelity Level	10.05	2	5.02	.26	.77
Feedback Level	27.71	2	13.86	.73	.49
Physical x Feedback	150.21	4	37.55	1.98	.11
Error	1,539.17	81	19.00		

TABLE 2

Summary ANOVA of Mean Number of Solutions
for the Various Simulator Training Groups

Source	SS	df	MS	F	Tail Prob.
Between Subjects	1152.40	1	1152.40		
Physical Fidelity Level	.63	2	.31	.12	.89
Feedback Level	5.61	2	2.80	1.03	.36
Physical x Feedback	4.43	4	1.11	.41	.80
Error	220.39	81	2.72		

TABLE 3

Summary ANOVA of Mean Times-To-Solution
for the Various Simulator Training Groups

Source	SS	df	MS	F	Tail Prob.
Between Subjects	1,242,562.50	1	1,242,562.50		
Physical Fidelity Level	19,217.02	2	9,608.51	3.24*	.04
Feedback Level	58,674.57	2	29,337.29	9.88**	.0001
Physical x Feedback	9,907.46	4	2,476.87	.83	.51
Error	240,398.83	81	2,967.89		

* p<.05
** p<.001

TABLE 4

Number of Tests, Means and Standard Deviations
for Training Groups During the Transfer Test

			Physical Fidelity		
			High	Medium	Low
Feedback Level	Full	M	7.93	8.06	6.73
		SD	5.10	3.17	2.37
	Partial	M	6.38	9.65	10.62
		SD	2.94	5.57	4.74
	No	M	10.06	8.71	6.88
		SD	4.15	6.33	3.14

TABLE 5

Number of Solution Attempts, Means and Standard Deviations for Training Groups During the Transfer Test

		Physical Fidelity		
		High	Medium	Low
Feedback Level	Full	M 3.16 SD 2.34	M 3.27 SD 1.14	M 3.74 SD 1.71
	Partial	M 3.64 SD .99	M 4.01 SD 1.72	M 4.15 SD 2.38
	No	M 3.58 SD 1.22	M 3.59 SD 1.40	M 3.07 SD 1.31

TABLE 6

Times-to-Solution (Sec.), Means and Standard Deviations for Training Groups During the Transfer Test

		Physical Fidelity		
		High	Medium	Low
Feedback Level	Full	M 73.67 SD 20.66	M 100.47 SD 33.61	M 107.34 SD 29.33
	Partial	M 76.71 SD 21.42	M 99.19 SD 28.02	M 141.27 SD 87.25
	No	M 144.81 SD 37.91	M 161.02 SD 51.37	M 153.02 SD 106.59

TABLE 7

Numbers of Subjects in Each of the Training Groups Consistently Choosing Logical (L), Sequential (S) or Random (haphazard) (R) Strategies During Reference System Testing

		Physical Fidelity		
		High	Medium	Low
Feedback Level	Full	R 0 S 3 L 6	R 1 S 1 L 7	R 0 S 0 L 8
	Partial	R 0 S 2 L 8	R 1 S 2 L 6	R 0 S 0 L 8
	No	R 1 S 1 L 8	R 0 S 1 L 9	R 0 S 0 L 8

TABLE 6

Numbers and Percentages of Subjects in Each of the Training Groups Using a Consistent (more than 60% of time) Strategy During Reference System Testing

		Physical Fidelity			
		High	Medium	Low	
Feedback Level	Full	9 90%	9 90%	8 80%	86.6%
	Partial	10 100%	9 90%	8 80%	90%
	No	9 90%	10 100%	8 80%	90%
		93.3%	93.3%	80%	

Table 9

Varimax Rotated Factor Matrix

	Factor 1 "Time"	Factor 2 "Test"	Factor 3 "Solution"
TTIME	.740	.509	.046
TFS	.674	.281	-.402
ITT	.831	-.312	-.015
IRT	.941	-.103	-.006
NTEST	-.226	.854	.269
TREP	-.003	.818	.131
NSOL	-.026	.116	.918
SOLREP	.068	.275	.789

Table 10

Significant Correlations of Individual Differences with Experimental Task Performance Criteria Across All Conditions

	Individual Differences														
					VPI										
	GEFT	BMC	GRE	LOC	R	I	S	C	E	A	SC	M	ST	F	AQ
Solution															
SOLREP	-.18*		-.24*				-.19*								
NSOL	-.27**		-.29*			-.20*									
Time															
ITT			.25*			.26*									
TFS								.20							
Total time															
IRT		.23*	.25*			.27*						.24*			
Tests															
NTests		-.27**	-.34***		-.20*				.25*						
TREP		-.26*					-.20*		.20*						

* p<.05

** p<.01

*** p<.001

Table 11

Significant Correlations Between Individual Difference Measures and The Dependent Variables of The "Time" Factor For Each Level of Training

Tng Cond	Dep Var	Individual Differences														
						VPI										
		GEFT	BMC	GRE A	LOC	R	I	S	C	E	A	SC	M	ST	F	AQ
Hi	ITT						.33*									
	TFS	-.50**														
Phys	TTime				.33*											
	IRT														-.36*	
Med	ITT		.54**	.45**												-.45*
	TFS					.43*	.32*							-.37*		
Phys	TTime															
	IRT		.50**	.44*			.40*									
Lo	ITT															
	TFS									.35*						
Phys	TTime															
	IRT															
Hi	ITT															
	TFS	-.46**														
Fdbk	TTime	-.55***														
	IRT															
Med	ITT			.33*												-.33*
	TFS															
Fdbk	TTime															
	IRT															-.34*
Lo	ITT						.50**									
	TFS								.58***	.39*		-.3**		-.40*		
Fdbk	TTime		-.42*													
	IRT						.54**									

* p<.05
** p<.01
*** p<.001

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Table 12

Significant Correlations Between Individual Difference Measures and The Dependent Variables of The "Test" Factor For Each Level of Training

Tng Cond	Dep Var	Individual Differences															
						VPI											
		GEFT	BMC	GRE A	LOC	R	I	S	C	E	A	SC	M	ST	F	AQ
Hi Phys	NTest																
	TREP				.35*												
Med Phys	NTest		-.48**	-.40*						.35*							
	TREP																
Lo Phys	NTest					-.33*				.33*							
	TREP				-.37*												
Hi Fdbk	NTest*			-.39*				.33*									.34*
	TREP					.51**											
Med Fdbk	NTest	-.35*	-.34*	-.54**					.39*	.37*							
	TREP		-.35*	-.40*				-.39*									
Lo Fdbk	NTest																
	TREP																

* p<.05
** p<.01

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Table 13

Significant Correlations Between Individual Difference Measures and The Dependent Variables of the "Solution" Factor for Each Level of Training

Tng Cond	Dep Var	Individual Differences														
						VPI										
		GEFT	BMC	GRE A	LOC	R	I	S	C	E	A	SC	M	ST	F	AQ
Hi Phys	NSOL				.38*											
	SOLREP															
Med	NSOL			-.34*			-.58***									
	SOLREP			-.36*			-.33*									
Lo Phys	NSOL	-.36*		-.42*				-.37*								
	SOLREP			-.43*	-.37*											
Hi Fdbk	NSOL	-.40*		-.38*												
	SOLREP															
Med Fdbk	NSOL						-.56**									
	SOLREP															
Lo Fdbk	NSOL		-.40*			-.55***			-.44*			.59***		.41*		
	SOLREP				.33*							.37*				

* p .05

** p .01

*** p .001

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